EXPLORING TRANSIT AND TNC INTERACTIONS USING SPATIOTEMPORAL TRIP DATA

Project ID # VAN042

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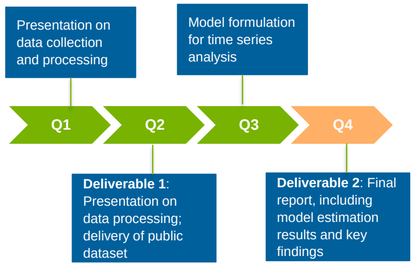
OBJECTIVES & RELEVANCE

- Many metropolitan regions have suffered significant transit ridership loss over the past decade, with bus declines of over 25% in some cases
- Losses overlap with the introduction of Transportation Network Companies (TNCs), giving a seeming correlation in the phenomena
- However, additional factors may be contributing, including:
  - changing populations, shifting land use patterns, transit service changes, macro-economic factors
- Necessary to understand causal relationships between these phenomena before cities and other agencies can act
- Conducted a detailed disaggregate analysis of long-term transit ridership data and TNC trip patterns to determine relationships between TNC ridership and transit ridership for similar areas
- Novel spatio-temporal analysis of trip level data helped understand trends in ridership changes across services

MILESTONES



PROJECT OVERVIEW

Timeline	Barriers Addressed
• Project start date : July FY20 • Project end date : June FY21 • Percent complete: 100%	• Lack of available data • Complex statistical modeling required to understand data correlations
Budget	**Partners**
• FY20 Funding : $150K	• George Mason University • Chicago Transit Authority

DATA SOURCES

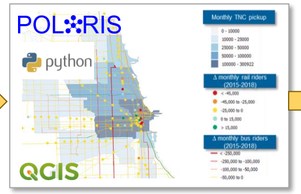
Source	Description
TNC Trip data (Chicago Data Portal)	• Two datasets: OD pairs by community area and census tract • Evaluate TNC usage over time to compare to transit usage
Transit data (cta)	• Stop-level boardings and alightings • OD estimations • Route-level ridership
Major events	• DB of major events in Chicago from 2018-2020 by date, time and tract location
Traffic flow data (Illinois Department of Transportation)	• Highway loop detectors for hourly speed and volumes on Chicago-area highways

APPROACH

Data Collection and Processing → **GIS & exploratory analysis** → **Space/Time-series modeling & analysis**

- Combine CTA, TNC and network data from 2010-2020 time period
- Develop time series network, land use and population data, etc.
- Explore other sources of TNC trip data

- Correlate TNC, taxi and transit data using GIS
- Route-to-OD pair analysis using POLARIS router
- Exploratory modeling combining multiple datasets



Model

$$Y_{kt} \sim f(y_{kt} \mid \mu_{kt}, \nu^2)$$
$$g(\mu_{kt}) = x_{kt}^T\beta + O_{kt} + \psi_{kt}$$
$$\beta \sim N(\mu_\beta, \Sigma_\beta)$$

Random effect

$$\psi_{kt} = \phi_k + (\alpha + \delta_k)\left(\frac{t - \bar{t}}{N}\right)$$

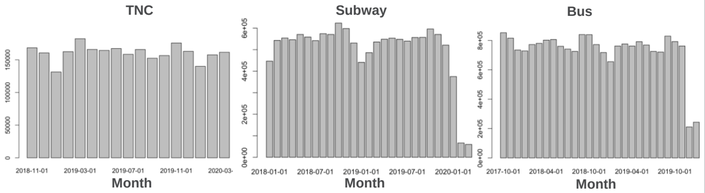
Thus the temporal pattern is modeled by a local trend δ_i and the spatial correlations are modeled via ϕ_i. Both are random effects, which are conditionally normal.

$$\phi_k \mid \phi_{-k}, W \sim N\left(\frac{1}{c}\sum_{j=1}^{K} w_{kj}\phi_j, \frac{\tau_{int}^2}{c}\right), \quad c = \sum_{j=1}^{K} w_{kj} - 1 + 1/\rho_{int}$$
$$\delta_k \mid \delta_{-k}, W \sim N\left(\frac{1}{q}\sum_{j=1}^{K} w_{kj}\delta_j, \frac{\tau_{slo}^2}{q}\right), \quad q = \sum_{j=1}^{K} w_{kj} - 1 + 1/\rho_{slo}^2$$
$$\tau_{int}^2, \tau_{slo}^2 \sim IG(a, b)$$
$$\rho_{int}, \rho_{slo} \sim Uniform(0, 1)$$
$$\alpha \sim N(\mu_\alpha, \sigma_\alpha^2)$$

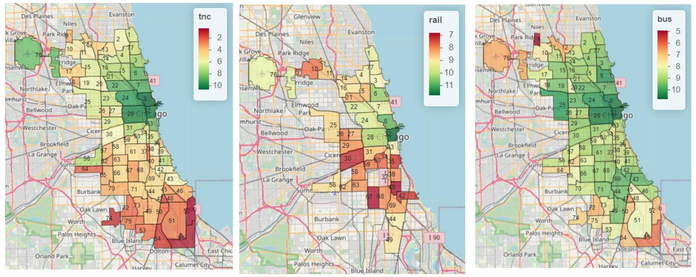
Each community area has its own linear trend with intercept ϕ_k and slope $\alpha + \delta_k$. Here ρ_{int}, ρ_{slo} are spatial dependence parameters, with values of one corresponding to strong spatial smoothness that is equivalent to the intrinsic CAR prior proposed by Besag et al. (1991), while values of zero correspond to independence (for example if ρ_{slo} then $\delta_k \sim N(0, \tau_{slo}^2)$.

ACCOMPLISHMENTS: DATA ANALYSIS

- **Data analysis** demonstrates underlying trends in ridership
- **Temporal data analysis**:
  - Data from 11/18-02/20 shows total trips are essentially flat across all three modes, with slight decrease in bus and TNC ridership and unchanged subway ridership
  - Small number of OD pairs contribute most trips, with the average OD number of daily trips of about ~100
  - Analysis ignores COVID impacted ridership after 02/2020

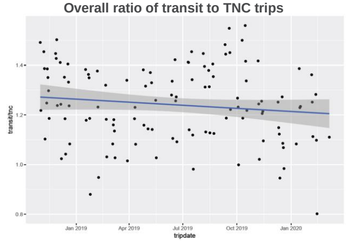


- **Spatial data analysis**
  - Rail and TNC usage is highly concentrated in Chicago central business district
  - TNC usage more widely distributed in wealthier residential/entertainment districts near the CBD along with much higher concentration of trips at the airports
  - Bus usage more evenly distributed throughout the city



- **Exploratory analysis:**
  - Slight negative trend in overall ratio of transit to TNC ridership over time in Chicago
  - Unclear relationship at OD-pair level
  - Detailed analysis of spatio-temporal correlations needed

Overall ratio of transit to TNC trips

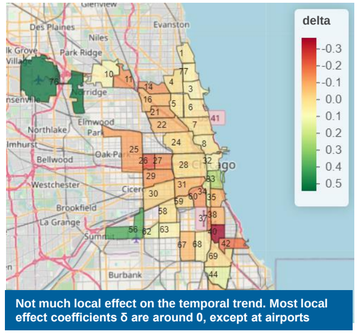


ACCOMPLISHMENTS: MODEL RESULTS

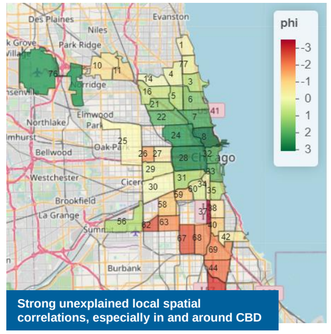
- Estimation results for Poisson distributed TNC counts

	Median	2.5%	97.5%
(Intercept)	0.8069	0.1768	1.4466
log(bus)	0.2332	0.1837	0.2796
log(rail)	0.3932	0.3489	0.4402
alpha	-0.0847	-0.1069	-0.0605
tau2.int	3.3423	2.2283	5.3536
tau2.slo	0.0406	0.0237	0.0712
rho.int	0.7319	0.3979	0.9496
rho.slo	0.4749	0.1174	0.8667

- Bus and rail move in the same direction as TNC
- TNC ridership has closer relationship to rail ridership (β=0.39) than bus ridership (β=0.23)
- Overall, the temporal trend is slightly negative α=−0.08
- *tau2.int* - spatial random effect variance (τ^2_{int}) - is large (large fraction of variance unexplained by variance in transit)
- *tau2.slo* - temporal trend variance (τ^2_{slo}) - is low, which corresponds to initial observation of not much change in data over time (for the observed time period)
- *rho.int* which is the strength of the spatial correlation is high (ρ_{int}=0.73)



Not much local effect on the temporal trend. Most local effect coefficients δ are around 0, except at airports



Strong unexplained local spatial correlations, especially in and around CBD

SUMMARY & PROPOSED FUTURE RESEARCH

- Summary and key findings:
  - Identified relevant data sets to perform spatio-temporal analysis, including time series of transit and TNC trips
  - Processed data to pair TNC trips to transit trips
  - Extended the Bernardinelli, Clayton, Pascutto, Montomoli, Ghislandi, and Songini (1995) model for this analysis
  - Exploratory analysis shows high degree of similarity between TNC and subway ridership, overall negative trend in TNC to transit trip ratio
  - Model results demonstrate high degree of relationship between TNC and rail with strong spatial relationships between areas experiencing high TNC ridershp
  - Temporal correlations seem to be mostly related to policy changes (i.e. airport pickups), otherwise mostly flat
- Proposed future research:
  - Explore various external factors which contribute to high unexplained variance (i.e. Incorporate external events and weather databases, population changes, land use changes)
  - Extend analysis for longer time periods, especially during high TNC growth, through additional data collection

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